

Atmos. Meas. Tech. Discuss., referee comment RC3  
<https://doi.org/10.5194/amt-2021-48-RC3>, 2021  
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## Reply on AC2

Anonymous Referee #3

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Referee comment on "Are elevated moist layers a blind spot for hyperspectral infrared sounders? A model study" by Marc Prange et al., Atmos. Meas. Tech. Discuss.,  
<https://doi.org/10.5194/amt-2021-48-RC3>, 2021

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Thanks to the authors for clarifying. I reread the paper with their response in mind and acknowledge that there is value in studying the information content and retrievability of target weather/climate features. Specifically, the authors focus on demonstrating the observing capability of passive infrared sounders with respect to elevated moist layers (EMLs). They do this using simulated IASI radiances of model atmospheres over ocean and in clear skies.

The authors presented their work clearly and accurately. Their paper reads well and has a logical flow. My primary concern is with the scientific value of their work. Their findings are not new, their experimental set up is naive, their test case(s) simplistic and they fail to recognize the work by others on hyperspectral infrared sounders from the past four decades. IASI has been in orbit since 2006. Its predecessor, AIRS, was launched in 2002 and both instruments have since seen two CrIS instruments join them in low Earth orbit. At the turn of the century, these hyperspectral infrared sounders revolutionized space-based vertical atmospheric observations. Now, we have nearly two decades of real measurements publicly available as a scientific community and well documented retrieval products from multiple different algorithms with which to study weather and climate phenomena. The existing record of retrieval products and the algorithms they are based on is by no means perfect or complete, but I fail to see how the work presented in this paper contributes to this body of knowledge.

### General notes:

Hyperspectral infrared sounders have hundreds of channels that allow one to apply sophisticated channel selection methods (e.g., Gambacorta and Barnett, 2011; Coopmann et al., 2020; Rabier et al., 2002; Fourrié and Rabier, 2004; Fourrié and Thépaut, 2003; Engelen and Bauer, 2014; Collard, 2007; Ventress and Dudhia, 2014; Martinet et al., 2014; Chang et al., 2020) to stabilize and maximize information content for a target variable. As reader and reviewer, I think Section 2.1 can be strengthened with a short description of the main principles of the method they employed, followed by a justification for their total of 1845 channels. That is a lot of channels. Why did the authors not thin it down, given the large degree of redundant information in these channels?

As far as different retrieval methods go, there are many excellent examples. I am listing here a few that focus on water vapor profiles (Smith and Weisz, 2018; Smith and Barnett,

2020; Smith et al., 2012, 2015; Susskind et al., 2003, 2014; Smith and Barnett, 2019; DeSouza-Machado et al., 2018; Irion et al., 2018; Weisz et al., 2013; Maddy et al., 2009).

An interesting aspect of this study is the author's choice of using temperature channels from the shortwave IASI band. This is an unusual choice because, historically, radiative transfer models generated large biases for the shortwave channels due to non-LTE effects (Yin, 2016; DeSouza-Machado et al., 2007) that cause diurnal differences. This is mostly addressed in modern-era radiative transfer models (e.g., SARTA and RTTOV) so this effect is minimized so that data assimilation and retrieval teams are looking at the shortwave temperature channels anew. Do the authors see diurnal differences in their results? It will be interesting if the authors can repeat their study but with temperature channels from the longwave IASI band as comparison.

Can the authors include a paragraph in their Summary section stating their thoughts on the value of their results to future algorithm upgrades or new instruments, like IASI-NG? Here are examples of how National Weather Service forecasters in the USA use NUCAPS retrievals (NOAA-Unique Combined Atmospheric Processing System) (Esmaili et al., 2020; Berndt et al., 2020), and the value they find in mid-tropospheric moisture retrievals. I wonder if the authors have observed EMLs in any one of the operational, publicly available retrieval products from NUCAPS (CrIS and IASI), CLIMCAPS (AIRS and CrIS), AIRS V7 or the EUMETSAT IASI Level 2 products? Do these products fail to sufficiently capture the EMLs in question?

### **Specific notes:**

Line 57: Can the authors give examples of what they mean by "instrument issues"? Clouds would be another factor.

Line 72: Instead of simply stating "poses an inverse problem", I suggest preemptively qualifying this statement as "poses an under-constrained inverse problem".

Line 80: There are many examples in the literature of research and operational retrieval algorithms that employ OEM for hyperspectral IR sounders, namely AIRS, CrIS and IASI. To strengthen this statement and communicate awareness of these other systems, I recommend that the authors add citations to these other OEM algorithms.

Line 88: For those unfamiliar with the channel selection method of Schneider and Hase (2011), I recommend that the authors add a sentence or two explaining the basic premise. There are numerous approaches to selecting hyperspectral IR channels and I think a clarification and justification of the authors' choice will strengthen this work.

Line 90: The spectral signal of water vapor is sensitive to temperature, yes, but also mid-tropospheric methane, surface emissivity and temperature and nitrous oxide (to a lesser degree).

Lines 95-96: Can the authors substantiate this statement with a citation?

Line 97: I'm intrigued by the authors' choice of using shortwave CO<sub>2</sub> channels for retrieving temperature information. This is an unconventional choice as most operational retrieval and data assimilation algorithms employ longwave CO<sub>2</sub> channels for temperature information. Can the authors justify their choice and discuss the benefits of using these shortwave CO<sub>2</sub> channels?

Figure 1: I'm wondering if I read this figure correctly. Does each IASI channel in the range 1250 – 2000 cm<sup>-1</sup> have 1 x degree of freedom (DOF)? This appears too high. Can the authors explain how they defined their variables for the Rodgers (2000) DOF equation?

Lines 99-102: I return again to the question about the channel selection method employed. Does the Boukachaba et al. (2015) method use the same principles as Schneider and Hase (2011)? A total of 1845 channels. How many of these channels are used for water vapor information? What are the exact spectral ranges where these channels come from? How many DOF does this set of channels have for water vapor versus surface and air temperature? I'm wondering how much spectral redundancy the authors are factoring into their method and why.

Line 141: This is the first time I read of ARTS. For IASI radiative transfer calculations, I'm much more familiar with RTTOV. From reading this section, I conclude that the authors used ARTS for its "internal OEM module" (Line 155), and not for its more accurate shortwave radiative transfer calculations. Is this correct? And are the authors confident that ARTS calculate non-LTE effects for IASI shortwave IR channels correctly? What vertical grid does ARTS employ?

Line 207: "making the term EML more graspable"... What does this mean?

Line 209: "EMLs can be described as layers of anomalously large humidity...". This is a very awkward statement that I struggle to understand.

Line 210: "one unconsciously also envisions"? I suggest rewriting this paragraph. It is difficult to follow.

Paragraph starting on line 215: I fully agree with the authors statement and appreciate their clear explanation here.

Line 234: As made clear from the beginning, the study the authors present here is in response to the findings by Stevens et al. (2017). I see the value in using the same atmospheric test case and this makes me wonder if Stevens et al. (2017) also used ARTS? The results the authors present here draws a different conclusion, but how much of that is due to differences in experimental set up, e.g., choice of radiative transfer model, channel subsets, simultaneous retrieval of air and surface temperature, etc. I'm curious to know how the water vapor averaging kernels compare between your study and that of Stevens et al. (2017). Did the authors achieve a similar signal-to-noise?

Line 271: This statement starting with "Note that..." should be introduced and explained early on in the text to avoid creating the confusion that I now find myself in as reader and reviewer.

Line 281: ". It shows that the EML strength  $s_{anom}$  of retrieval setup 1 is about half the value of the true state". What does this mean?

Table 2: I assume the authors converted profiles in pressure units to distance units using the geopotential height calculation? It will be helpful if the caption explain what "Strength" means. Of the four quantities reported here, "Strength" is the most obscure and abstract, being without units.

Lines 287-299: I appreciate the authors' clear, direct response to Stevens et al. (2017), refuting their notion that hyperspectral IR measurements lack mid-tropospheric water vapor information. I agree with the authors' main conclusions here, but as stated earlier, it is well established that the retrieval of water vapor information depends on knowledge about temperature. I suggest that the authors acknowledge this with relevant citations. E.g., as far as retrieval systems go, there is the simultaneous approach (Smith et al., 2012; Weisz et al., 2013; Irion et al., 2018) and sequential approach (Smith and Barnett, 2020, 2019; Susskind et al., 2014, 2003; Maddy et al., 2009) to account for temperature uncertainty in water vapor retrievals.

Line 316: "Values close to 1 indicate a good sensitivity of the retrieval." This sentence is misleading since it appears to refer to the black line in Fig. 5(a) and (c). The correct statement should be: Averaging kernel values close to 1 indicate strong sensitivity of the retrieval to the true state. But because the inversion of hyperspectral IR measurements into water vapor profiles is, by definition, an under constrained, ill-posed solution, averaging kernels never approach 1 (see Smith and Barnett, 2020 and references therein).

While accurate, this discussion lacks depth without citations and only a single example of "an exemplary" EML case. I wonder how the water vapor averaging kernels for EML's change under different temperature conditions, such as day versus night. Can the authors include a sentence on the sensitivity of averaging kernels to different EML cases?

## References

Berndt, E. B., Smith, N., Burks, J., White, K., Esmaili, R., Kuciauskas, A., Duran, E., Allen, R., LaFontaine, F., and Szkodziniski, J.: Gridded Satellite Sounding Retrievals in Operational Weather Forecasting: Product Description and Emerging Applications, 12, 3311, <https://doi.org/10.3390/rs12203311>, 2020.

Chang, S., Sheng, Z., Du, H., Ge, W., and Zhang, W.: A channel selection method for hyperspectral atmospheric infrared sounders based on layering, 13, 629–644, <https://doi.org/10.5194/amt-13-629-2020>, 2020.

Collard, A. D.: Selection of IASI channels for use in numerical weather prediction, 133, 1977–1991, <https://doi.org/10.1002/qj.178>, 2007.

Coopmann, O., Guidard, V., Fourrié, N., Josse, B., and Marécal, V.: Update of Infrared Atmospheric Sounding Interferometer (IASI) channel selection with correlated observation errors for numerical weather prediction (NWP), 13, 2659–2680, <https://doi.org/10.5194/amt-13-2659-2020>, 2020.

DeSouza-Machado, S., Strow, L. L., Tangborn, A., Huang, X., Chen, X., Liu, X., Wu, W., and Yang, Q.: Single-footprint retrievals for AIRS using a fast TwoSlab cloud-representation model and the SARTA all-sky infrared radiative transfer algorithm, 11, 529–550, <https://doi.org/10.5194/amt-11-529-2018>, 2018.

DeSouza-Machado, S. G., Strow, L. L., Hannon, S. E., Motteler, H. E., Lopez-Puertas, M., Funke, B., and Edwards, D. P.: Fast forward radiative transfer modeling of 4.3  $\mu\text{m}$  nonlocal thermodynamic equilibrium effects for infrared temperature sounders, 34, <https://doi.org/10.1029/2006GL026684>, 2007.

Engelen, R. J. and Bauer, P.: The use of variable CO<sub>2</sub> in the data assimilation of AIRS and IASI radiances, 140, 958–965, <https://doi.org/10.1002/qj.919>, 2014.

Esmaili, R. B., Smith, N., Berndt, E. B., Dostalek, J. F., Kahn, B. H., White, K., Barnett, C. D., Sjöberg, W., and Goldberg, M.: Adapting satellite soundings for operational forecasting within the hazardous weather testbed, 12, 886, <https://doi.org/10.3390/rs12050886>, 2020.

Fourrié, N. and Rabier, F.: Cloud characteristics and channel selection for IASI radiances in meteorologically sensitive areas, 130, 1839–1856, <https://doi.org/10.1256/qj.03.27>, 2004.

Fourrié, N. and Thépaut, J.-N.: Evaluation of the AIRS near-real-time channel selection for application to numerical weather prediction, 129, 2425–2439, <https://doi.org/10.1256/qj.02.210>, 2003.

Gambacorta, A. and Barnet, C. D.: Methodology and information content of the NOAA NESDIS operational channel selection for the Cross-Track Infrared Sounder (CrIS), 2011.

Irion, F. W., Kahn, B. H., Schreier, M. J., Fetzer, E. J., Fishbein, E., Fu, D., Kalmus, P., Wilson, R. C., Wong, S., and Yue, Q.: Single-footprint retrievals of temperature, water vapor and cloud properties from AIRS, 11, 971–995, <https://doi.org/10.5194/amt-11-971-2018>, 2018.

Maddy, E. S., Barnet, C. D., and Gambacorta, A.: A computationally efficient retrieval algorithm for hyperspectral sounders incorporating a-priori information, 6, 802–806, <https://doi.org/10.1109/LGRS.2009.2025780>, 2009.

Martinet, P., Lavanant, L., Fourrié, N., Rabier, F., and Gambacorta, A.: Evaluation of a revised IASI channel selection for cloudy retrievals with a focus on the Mediterranean basin, 140, 1563–1577, <https://doi.org/10.1002/qj.2239>, 2014.

Rabier, F., Fourrié, N., Chafaï, D., and Prunet, P.: Channel selection methods for Infrared Atmospheric Sounding Interferometer radiances, 128, 1011–1027, <https://doi.org/10.1256/0035900021643638>, 2002.

Smith, N. and Barnet, C. D.: Uncertainty Characterization and Propagation in the Community Long-Term Infrared Microwave Combined Atmospheric Product System (CLIMCAPS), 11, 1227, <https://doi.org/10.3390/rs11101227>, 2019.

Smith, N. and Barnet, C. D.: CLIMCAPS observing capability for temperature, moisture, and trace gases from AIRS/AMSU and CrIS/ATMS, 13, 4437–4459, <https://doi.org/10.5194/amt-13-4437-2020>, 2020.

Smith, N., Smith, W. L., Weisz, E., and Revercomb, H. E.: AIRS, IASI and CrIS retrieval records at climate scales: An investigation into the propagation systematic uncertainty, JAMC, 54, 1465–1481, 2015.

Smith, W. L. and Weisz, E.: Dual-regression approach for high-spatial-resolution infrared soundings, 7, 297–311, <https://doi.org/10.1016/B978-0-12-409548-9.10394-X>, 2018.

Smith, W. L., Weisz, E., Kireev, S. V., Zhou, D. K., Li, Z., and Borbas, E. E.: Dual-regression retrieval algorithm for real-time processing of satellite ultraspectral radiances, JAMC, 51, 1455–1476, <https://doi.org/10.1175/JAMC-D-11-0173.1>, 2012.

Susskind, J., Barnet, C. D., and Blaisdell, J. M.: Retrieval of atmospheric and surface parameters from AIRS/AMSU/HSB data in the presence of clouds, IEEE TGRS, 41, 390–409, 2003.

Susskind, J., Blaisdell, J. M., and Iredell, L.: Improved methodology for surface and atmospheric soundings, error estimates, and quality control procedures: the atmospheric infrared sounder science team version-6 retrieval algorithm, 8, 084994, <https://doi.org/10.1117/1.JRS.8.084994>, 2014.

Ventress, L. and Dudhia, A.: Improving the selection of IASI channels for use in numerical weather prediction, 140, 2111–2118, <https://doi.org/10.1002/qj.2280>, 2014.

Weisz, E., Smith, W. L., and Smith, N.: Advances in simultaneous atmospheric profile and cloud parameter regression based retrieval from high-spectral resolution radiance measurements, J. Geophys. Res. Atmos., 118, 6433–6443, <https://doi.org/10.1002/jgrd.50521>, 2013.

Yin, M.: Bias characterization of CrIS shortwave temperature sounding channels using fast NLTE model and GFS forecast field, 121, 1248–1263, <https://doi.org/10.1002/2015JD023876>, 2016.